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(पहला पुनरीक्षण)

Indian Standard

THERMOSTAT METALS – DETERMINATION OF FLEXIVITY

(*First Revision*)

UDC 669·018·4-418·2 : 620·115·8

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

November 1991 Price Group 4

Mechanical Testing of Metals Sectional Committee, MTD 3

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after draft finalized by the Mechanical Testing of Metals Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Thermostat metals are used for making bimetallic thermometers and thermostatic controls, their main applications being in (i) temperature indication and control (ii) compensation devices in various mechanisms (iii) fire-alarms and circuit-breakers, etc.

This standard was first published in 1964. In this revision following changes have been made:

a) The requirements of test specimen have been modified;

b) Test method for measuring flexivity of spiral coils has been added; and

c) Precision and Bias have been specified.

In revising this standard assistance has been derived from following standards published by American Society for Testing and Materials:

ASTM B 106 : 84 Test Methods for Flexivity of Thermostat Metals

ASTM B 389 : 81 Test Method for Thermal Deflection Rate of Spiral and Helical Coils of Thermostat Metals

In reporting the results of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

THERMOSTAT METALS – DETERMINATION OF FLEXIVITY

(*First Revision*)

1 SCOPE

1.1 This standard specifies the procedures for determination of the flexivity of the thermostat metals (Method A) tested in the form of flat strips 0·30 mm or over in thickness and (Method B) tested in the form of spiral coils less than 0·30 mm in thickness.

1.2 Flexivity is determined for thermostat metal as a whole, no account being taken for the characteristics of the individual components.

2 TERMINOLOGY

2.1 Component

One of the laminate of a thermostat metal which in conjunction with the other component(s) determines the sensitivity to a curvature change with a temperature change.

2.2 Flexivity

2.2.1 *Flat Strips*

'*F*' the change of curvature of the longitudinal centre line (neutral axis) of the specimen per unit temperature change for unit thickness, given by the following equation:

$$F = \frac{(1/R_2) - (1/R_1) \, t}{T_2 - T_1} \qquad (1)$$

To determine the flexivity between any two temperatures T_1 and T_2 it is necessary to measure the curvature $1/R_1$ and $1/R_2$ at temperature T_1 and T_2 respectively. To find the curvature at either temperature, measure the distance (D) as shown in Fig 1. The curvature is given by the following equation:

$$1/R = 8D / (Q^2 + 4\,Dt + 4\,D^2) \qquad (2)$$

where

F = flexivity in mm/mm°C,

R = radius of curvature of the longitudinal centre line of the specimen in mm,

t = thickness of test specimen in mm,

Q = distance between support points in mm, and

D = for point support = perpendicular distance between the longitudinal centre lines of the lower surface of the specimen midway between the point support and the straight line joining the support points, mm.

2.2.2 *Spiral Coils*

'*F*' is defined by the following equation:

$F = 0{\cdot}015(1)\ 4\ dt/L$

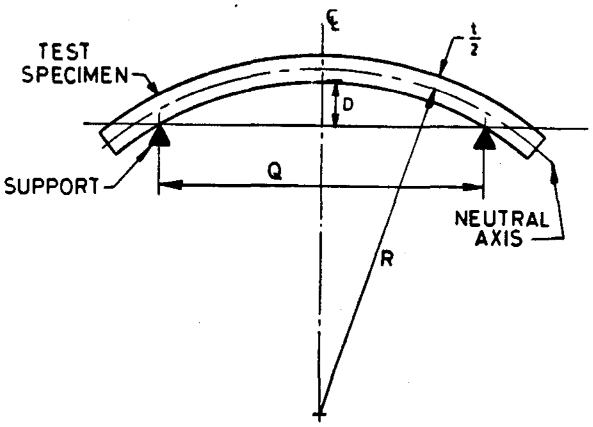

Fig. 1 Test for Flexivity of Thermostat Metals

where

F = flexivity in mm/mm°C,

d = thermal deflection rate of test specimen in angular degrees/°C $[(A_2-A_1)/(T_2-T_1)]$ where A_1 and A_2 are angular positions at temperature T_1 and T_2,

t = thickness of test specimen in mm, and

L = active length of test specimen in mm.

2.3 Thermostat Metal

A composite material consisting of two or more materials, metallic or otherwise having differing expansivities which causes an alteration of its curvature when its temperature is changed. Thermostat metal is in the form of sheet or strip.

METHOD A — FLAT STRIPS

3 APPARATUS

3.1 Specimen Carrier

It shall be provided with two conical supports for locating the specimen. The test length (that is, the distance between the point of contact of the specimen with one support and the point of contact of the specimen with the other support) shall be known to within ±0·13 mm and the line of plane passing through the points of contact shall be horizontal. The specimen carrier and supports shall hold the specimen without constraint so that the curvature, due to its deflection, will follow a vertical plane passing through the line joining the points of contact between specimen and supports.

3.2 Micrometer (Travelling Microscope, or Equivalent Device)

It shall be so connected to the specimen carrier that expansion during heating of the carrier or connecting parts will not cause appreciable displacement of the measuring device with respect to the supports.

3.3 Temperature Bath

A stirred liquid bath or uniformly heated enclosure, in which the specimen carrier, together with adjustable electric heating source is placed, by means of which the specimen can be maintained at the desired temperatures, with variation in temperature throughout the gauge length of the specimen not to exceed 0·5 percent of the temperature range used in the test.

3.4 Temperature Measuring Apparatus

It shall be of such accuracy that the individual temperatures shall be known to within 0·3°C.

3.5 Deflection Index

Means shall be provided for measuring the deflection of the specimen at a point midway between the points of support and along the vertical line intersecting the line joining the points of support. Such means may comprise a fused-quartz transmission rod disposed with its axis vertical and terminating in a point or knife-edge which shall engage the specimen midway between the points of contact with the supports. Such a transmission rod shall be mounted in such a manner that it is free to move in the direction of its axis. The rod shall bear at its free and an index suitable for microscope observation or else an electrical contact with which a micrometer will permit the changes of the deflection of specimen to be accurately observed. Alternatively the deflection of the midpoint of the specimen may be directly observed by optical means whose line of sight is horizontal and passes through the vertical line through the midpoint of the specimen. A micrometer screw with extended spindle making direct contact with the specimen may be used. In this case, electrical means shall be provided that will indicate contact without significant disturbance of the specimen. The measurement of the position of the midpoint of the test specimen shall be of such accuracy that the individual positions at the test temperatures shall be known to within ±0·005 mm.

3.5.1 If a transmission rod is used, it and any attached parts shall be of such weight or so counter weighed that they will not cause a deflection greater than 1% of the maximum to be produced by the action of the thermostat metal alone. When free, the thermostat metal assured very nearly a circular curvature. Concentrated loading at the centre of the specimen will cause the curvature to be other than circular and may cause significant errors in the evaluation of flexivity. The location of the line passing through the points of contact between specimen and supports shall be known with reference to the scale of the micrometer to within ± 0·05 mm.

4 TEST SPECIMEN

4.1 The test specimen shall be in the form of a strip that displays no apparent initial irregularity of curvature.

4.2 The maximum thickness shall not be greater than the minimum thickness by more than 2 percent of the later.

4.3 The width shall be related to the thickness in accordance with Fig. 2. Preferred widths are to be used whenever possible. The maximum width shall not exceed the minimum width by more than 2 percent of the later.

4.4 The length shall be such as to allow a distance between supports that bears the relation to the thickness in accordance with Table 1 and to allow a distance beyond the supports not less than the width.

4.5 The thickness of the specimen shall be determined within ±0·001 mm by means of a screw micrometer or an equivalent method.

NOTE — For specimen less than 1·27 mm in thickness, special precautions are necessary, such as the use of a micrometer reading directly to 0·001 mm or suitable optical methods may be used.

The average thickness may also be calculated from measurements of length, width, weight and density. When the density is unknown, it may be determined by weighing a sample of at least 10 g first in air and then in water. The density in grams per cubic centimetre is equivalent to the weight in air divided by the loss of weight due to submergence in water. The temperature of the water shall be approximately the same as that of the balance room to avoid errors due to convection currents. For the accuracy required, no corrections are necessary for the temperature of the water or for the buoyancy of the air. However, care shall be exercised to remove all air bubbles from the sample when weighing it in water and to avoid the presence of grease or oil films on the surface of the water. To this end it is recommended that after a preliminary cleaning to remove obvious dirt, the sample be attached to a fine wire to be used later in suspending it while weighing and throughly rinsed, first in ether, then alcohol and finally water, before immersing in the water to be used for weighing.

5 PREPARATION OF TEST SPECIMEN

5.1 After being roughly cut or sheared from the sample, finish the test specimen to size by careful machining or filing. Remove the amount of material extending a distance not less than twice the thickness along each edge of the specimen, to eliminate material damaged by preliminary shaping. Slit edges with a minimum of burr may also be used.

5.2 When the specimen has been finished to size, make any necessary reference marks (by such means as a sharp drill, scribing tool, or milling cutter) and determine and record their relative locations. Do not use center punches or similar means because of the distortion produced.

5.3 It is recommended that the grains run along the length of the specimen.

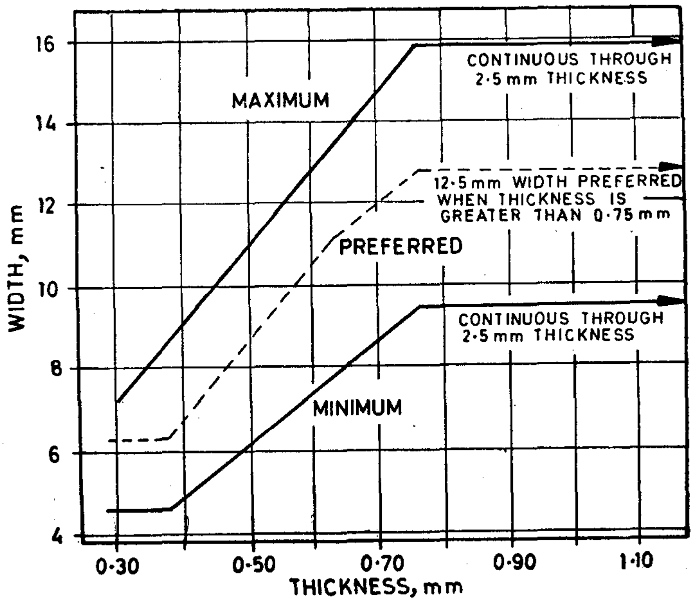

FIG. 2 WIDTH OF TEST SPECIMEN

Table 1 Gauge Length of Test Specimen (Method A)

(*Clause* **4.4**)

Specimen Thickness		Gauge Length
From	Up to and including	
mm	mm	mm
0·30	0·379	50·8 ± 12·7
0·38	0·509	63·5 ± 12·7
0·51	0·639	76·2 ± 12·7
0·64	0·759	88·9 ± 12·7
0·76	0·889	101·6 ± 12·7
0·89	1·139	114·3 ± 12·7
1·14	2·54	127·0 ± 12·7

6 PROCEDURE

6.1 Stabilization

After all preparatory work on the test specimen has been completed, subject it to a stabilizing heat treatment to relieve internal stresses. This treatment may consist in heating the specimen while free to bend, for a prescribed time and temperature. The details of the stabilizing procedure will depend upon the characteristics of the thermostat metal being tested and shall be as mutually agreed upon between the manufacturer and the purchaser.

6.2 Test Routine

Mount the specimen on the support on the specimen table, put the transmission rod in place and take a zero reading at room temperature. Apply slight mechanical pressure and then remove at a point near the center of the specimen. If appreciable ero shift is apparent with repeated applications of pressure, determine the cause and correct before proceeding with the test.

6.3 When satisfactory initial conditions have been established, make observations of deflection and temperature at room temperature and record the results.

6.4 Then adjust the temperature of the specimen to the next value desired. Measure and record the temperature of the specimen at points on or near the center and ends.

6.5 Then measure and record the deflection.

6.6 Remeasure and record the temperature measurements as described in **6.4**. If significant discrepancies of temperature or its distribution are found, correct them and again measure and record the deflection.

6.7 After having secured satisfactory temperature measurements and corresponding deflection data, establish the next chosen temperature and follow the preceding routine over the range of temperature agreed upon.

6.8 In all cases, make a final set of measurements at or near room temperature to determine whether or not there has been permanent distortion or any mechanical incident that would prevent determination of flexivity within the desired limits of accuracy. If such is evident, repeat the test under one of the following conditions as agreed upon by the manufacturer and the purchaser:

6.8.1 Test the same specimen over the same temperature range.

6.8.2 Test the same specimen over a different temperature range.

6.8.3 Test another specimen over the same temperature range.

6.8.4 Test another specimen over a different temperature range.

7 CALCULATION

For the calculation *see* **2.2.1** and Annex A.

8 REPORT

The report shall include the following:

a) Type of thermostat metal;
b) Dimensions of specimen;
c) Temperature and type of stabilizing heat treatment;
d) Temperature range of test; and
e) Flexivity.

9 PRECISION AND BIAS

The cumulative errors in the measurement of active length, temperature, thickness, and deflection positions can produce discrepancies between successive flexivity determinations on the same test specimen. Tables 2 and 4 show maximum cumulative errors using a statistical approach for various sample size, flexivities, and temperature differences (ΔT).

METHOD B — SPIRAL COILS

10 APPARATUS

10.1 Specimen Carrier/Holder

It shall provide means for securely holding the coil. It shall be preferably circular cross section whose diameter shall be as large as

Table 2 Maximum Cumulative Ferrous in Flexivity Determination of Flat Strips (Method A)

(*Item* 9)

Flexivity	t	Q	Maximum Error in Flexivity ± %		
			Δ T=	Δ T=	Δ T=
mm/mm°C	mm	mm	55·5°C	111·0°C	166·5°C
43 $\times 10^{-6}$	2·54	127·0	0·82	0·44	0·32
43 ,,	2·29	127·0	0·80	0·43	0·32
43 ,,	2·03	127·0	0·79	0·43	0·32
43 ,,	1·78	127·0	0·78	0·43	0·32
43 ,,	1·52	127·0	0·78	0·43	0·34
43 ,,	1·27	127·0	0·77	0·44	0·35
43 ,,	1·02	114·3	0·79	0·47	0·38
43 ,,	0·76	101·6	0·82	0·52	0·45
43 ,,	0·51	76·2	0·92	0·66	0·61
43 ,,	0·38	63·5	1·04	0·81	0·77
43 ,,	0·30	50·8	1·18	0·98	0·94
23 ,,	2·54	127·0	1·01	0·52	0·37
23 ,,	2·29	127·0	0·96	0·50	0·36
23 ,,	2·03	127·0	0·92	0·49	0·36
23 ,,	1·78	127·0	0·88	0·47	0·35
23 ,,	1·52	127·0	0·85	0·47	0·36
23 ,,	1·27	127·0	0·83	0·46	0·36
23 ,,	1·02	114·3	0·84	0·49	0·40
23 ,,	0·76	101·6	0·87	0·54	0·46
23 ,,	0·51	76·2	0·98	0·68	0·62
23 ,,	0·38	63·5	1·10	0·83	0·77
23 ,,	0·30	50·8	1·26	1·00	0·95
13 ,,	2·54	127·0	1·48	0·76	0·52
13 ,,	2·29	127·0	1·37	0·70	0·49
13 ,,	2·03	127·0	1·27	0·65	0·46
13 ,,	1·78	127·0	1·17	0·61	0·43
13 ,,	1·52	127·0	1·07	0·57	0·42
13 ,,	1·27	127·0	0·99	0·54	0·40
13 ,,	1·02	114.3	1·00	0·56	0·43
13 ,,	0·76	101·6	1·00	0·60	0·49
13 ,,	0·51	76·2	1·15	0·75	0·65
13 ,,	0·38	63·5	1·28	0·89	0·80
13 ,,	0·30	50·8	1·50	1·09	0·99
4 ,,	2·54	127·0	4·58	2·30	1·54
4 ,,	2·29	127·0	4·14	2·07	1·39
4 ,,	2·03	127·0	3·69	1·85	1·24
4 ,,	1·78	127·0	3·25	1·64	1·10
4 ,,	1·52	127·0	2·81	1·42	0·96
4 ,,	1·27	127·0	2·38	1·21	0·83
4 ,,	1·02	114·3	2·36	1·21	0·84
4 ,,	0·76	101·6	2·27	1·18	0·84
4 ,,	0·51	76·2	2·66	1·41	1·03
4 ,,	0·38	63·5	2·90	1·58	1·18
4 ,,	0·30	50·8	3·60	1·95	1·47

possible without touching the inner turn of the coil under any conditions of test temperatures. It shall be slotted across its diameter and to a depth greater than the width of the specimen. The width of the slot shall be slightly narrower than the thickness of the specimen so that the inner tab will be push fit in the slot. The slot shall be so positioned in the holder that the centre of rotation of the coil and the centre of the holder coincide.

10.2 Temperature Bath (*see* 3.3)

10.3 Temperature Measuring Apparatus (*see* 3.4)

10.4 Protractor

The angular position at each test temperature shall be measured by a protractor with minimum division of 0·5°.

10.5 Transmission Pointer

It shall be attached to the outer end of the spiral coil for transmitting the rotation of the coil so that rotation can be read on the protractor. The pointer shall be of lightweight construction and attached to the coil by suitable means so that the movement of those portions of the coil that do not contribute to the movement of the coil with a temperature change shall not influence the rotation of the pointer.

11 TEST SPECIMENS

11.1 The test specimen shall be in the form of a spiral coil which displays no apparent irregularities. The coil shall be wound with the low expanding side outside, an inside diameter of 7·1 mm, an inside tab length of 4·8 mm, an outside radius of 11·9 mm, and no outer tab.

11.2 The maximum thickness shall be greater than the minimum thickness by more than 1 percent of the later.

11.3 The thickness of the specimen shall be determined within ±0·002 mm, by means of a screw micrometer or equivalent method.

11.4 The active length, which is that portion of the coil which is free to deflect when subjected to a change in temperature and does not include that portion of the coil which is used for mounting shall be known to within ±0·4 mm·

11.5 The width and active length shall be related to the thickness in accordance with Table 3.

11.6 The required width shall be produced by slitting and the edges shall have a minimum of burrs.

12 PROCEDURE

12.1 Subject the specimen to stabilizing heat treatment to relieve internal stresses. The details of the stabilizing procedure will depend upon the characteristics of the thermostat metal being tested and shall be mutually agreed upon between the manufacturer and the purchaser.

12.2 Mount the specimen with the pointer attached on the specimen holder. Place the specimen holder with the specimen in the bath of the desired temperature. When temperature of the specimen has reached the bath temperature, measure and record the angular position of the transmission pointer and the bath temperature.

12.3 Establish the next chosen temperature and measure and record the position of the pointer and the bath temperature.

13 CALCULATION

For the calculation, (*see* **2.2.2**) and Annex A.

14 REPORT (*see* 8)

15 PRECISION AND BIAS (*see* 9)

Table 3 Width and Length of Test Specimen (Method B)

(*Clause* **11.5**)

Specimen Thickness mm	Width mm	Active Length mm
0·102	2·8	203
0·127	3·2	254
0·152	3·2	254
0·178	3·6	254
0·203	3·6	254
0·229	4·0	254
0·254	4·8	305
0·280	4·8	305
0·302	4·8	305

Table 4 Maximum Cumulative Errors in Flexivity Determination (Method B)

(*Item* 9)

Flexivity	t	Q	Maximum Error in Flexivity, ± %		
mm/mm°C	mm	mm	ΔT= 55·5°C	ΔT= 111·0°C	ΔT= 166·5°C
43 × 10^{-6}	0·302	305	1·13	0·93	0·89
43 ,,	0·254	305	1·25	1·07	1·04
43 ,,	0·203	254	1·46	1·31	1·28
43 ,,	0·152	254	1·82	1·71	1·69
43 ,,	0·127	254	2·13	2·04	2·02
43 ,,	0·102	203	2·61	2·54	2·52
23 ,,	0·302	305	1·18	0·94	0·89
23 ,,	0·254	305	1·28	1·08	1·04
23 ,,	0·203	254	1·40	1·32	1·29
23 ,,	0·152	254	1·84	1·71	1·69
23 ,,	0·127	254	2·14	2·04	2·02
23 ,,	0·102	203	2·62	2·54	2·52
13 ,,	0·302	305	1·35	1·00	0·92
13 ,,	0·254	305	1·39	1·12	1·06
13 ,,	0·203	254	1·57	1·35	1·30
13 ,,	0·152	254	1·87	1·73	1·70
13 ,,	0·127	254	2·16	2·04	2·02
13 ,,	0·102	203	2·64	2·54	2·52
4 ,,	0·302	305	2·92	1·63	1·26
4 ,,	0·254	305	2·58	1·56	1·28
4 ,,	0·203	254	2·58	1·70	1·48
4 ,,	0·152	254	2·44	1·90	1·77
4 ,,	0·127	254	2·52	2·14	2·07
4 ,,	0·102	203	2·94	2·62	2·56

ANNEX A

(For Information Only)

(*Items* 7 and 13)

A-1 SAMPLE CALCULATION FOR FLEXIVITY (FLAT STRIPS, METHOD A)

A-1.1 Test Information

Dimension of specimen:

Thickness	0·513 mm
Width	8·76 mm
Total length	108 mm

Length between point supports 76 mm

Test data:

Temperature:

$T_1 = 36{\cdot}8°C$
$T_2 = 94{\cdot}9°C$

Distance:

$D_1 = -\ 0{\cdot}818$ mm
$D_2 = 1{\cdot}387$ mm

A-1.2 Calculations

Equations 1 and 2 of **2.2** when combined give the equation:

$$F = (\ 8\ t/[T_2 - T_1])\ X$$

$$X\ ([\ D_2/(Q^2 - 4\ D_2 t + 4D_2^2\ )] - [\ D_1/(Q^2 - 4\ D_1 t + 4D_1^2\ )])$$

$$F = \left(\frac{8\ (\ 0{\cdot}513\ )}{94{\cdot}9 - 36{\cdot}8}\right) X$$

$$X = \left(\frac{1{\cdot}387}{(76{\cdot}0)^2 + 4\ (1{\cdot}387)\ (0{\cdot}513) - 4(1{\cdot}387)^2} - \frac{-0{\cdot}818}{(76{\cdot}0)^2 + 4(-0{\cdot}818)\ (0{\cdot}513) + 4(-0{\cdot}818)^2}\right)$$

$$F = 0{\cdot}00002693/°C$$

A-2 SAMPLE CALCULATION FOR FLELXIVITY (SPIRAL COIL, METHOD B)

A-2.1 Test Information

Dimensions of Specimen:

Thickness	0·277 mm
Width	4·76 mm
Total	309·6 mm
Active length	304.8 mm

Test Data:

Temperature:

$T_1 = 10{\cdot}7\,^\circ\mathrm{C}$

$T_2 = 93{\cdot}2\,^\circ\mathrm{C}$

Angular Position :

$A_1 = 12{\cdot}50^\circ$

$A_2 = 171{\cdot}25^\circ$

A-2.2 Calculations

$d = (A_2 - A_1) / (T_2 - T_1)$

$d = (171{\cdot}25 - 12{\cdot}50)/(93{\cdot}2 - 10{\cdot}7) = 1{\cdot}924$ angular degree/°C,

$F = 0{\cdot}015\,4$ dt/L

$= 0{\cdot}015\,4\ (1{\cdot}924)\ (0{\cdot}277)/304{\cdot}8$

$F = 0{\cdot}00002692/^\circ\mathrm{C}$

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